(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
15 March 2001 (15.03.2001)

PCT

(10) International Publication Number
WO 01/19060 A1

(51) International Patent Classification[7]: H04M 1/60

(21) International Application Number: PCT/US00/24203

(22) International Filing Date: 31 August 2000 (31.08.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
09/390,222 3 September 1999 (03.09.1999) US

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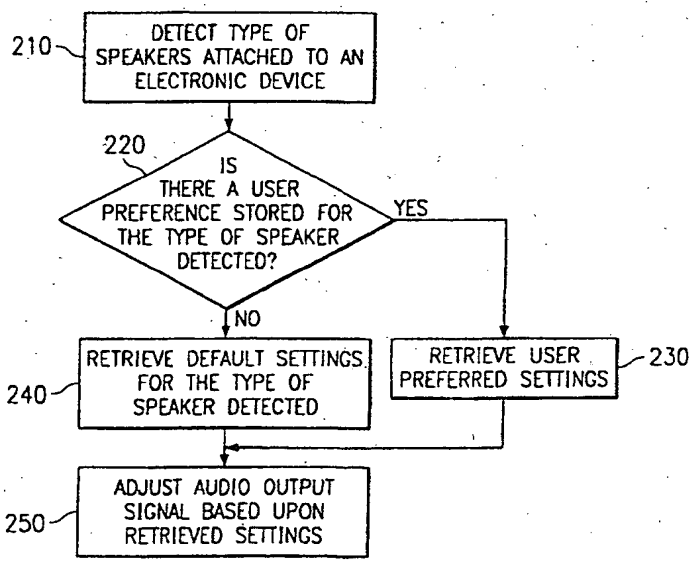
(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *With international search report.*
— *Before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments.*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: MOBILE COMMUNICATIONS DEVICE WITH SPEAKER DEPENDENT AUDIO ADJUSTMENT



(57) Abstract: A portable electronic device that produces an audio output signal, may have a plurality of speaker types connected to the device, and is capable of modifying the audio output signal to more effectively use the sound reproduction capabilities of the connected speakers. In addition to an internal speaker, many portable electronic devices have jacks for connecting external speakers. These external speakers generally have different audio and electrical characteristics than the internal speaker. In one embodiment disclosed herein, a mobile radio modifies its audio output signal to better match the type of external speaker being used by the mobile radio to reproduce sound.

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MOBILE COMMUNICATIONS DEVICE WITH SPEAKER DEPENDENT AUDIO ADJUSTMENT

Field of the Invention

This invention relates to electronic devices and, more particularly, to electronic devices that output an audio signal and may support a variety of speaker types and configurations.

Background

Many electronic devices, such as mobile phones, offer the option of using speakers other than the speaker built in to the electronic device. There are many types of these optional external speakers. Earpiece speakers, for example, are a common accessory for mobile phones. Kits for mounting a mobile phone in an automobile are also common accessories. These kits (known as "car kits") usually include an external audio amplifier and large external speakers that have greater acoustic impedance than the built-in speaker. The external audio amplifier typically supplies increased current to the external speakers so that the phone's audio signal magnitude can be increased for the noisy automobile environment.

Speakers are available in a variety of types. They can be categorized in types by several methods based on the properties of the speakers. Speakers can be categorized by types of transducer construction technology such as piezo-electric, ribbon, coil-and-magnet, etc. Speakers can be categorized by types of driver load such as free-space, sealed box, horn-

loaded, band-pass, labyrinth, vented cabinet, etc. They are also commonly typed by audio performance, such as midrange, tweeter, bass, etc. Regardless of which categorization method is chosen, different speaker types have different audio reproduction capabilities. For example, if typing speakers by construction technology, a piezo-electric type will have a different performance bandwidth than a large coil-and-magnet driven cone. As another example, if typing speakers by driver load, a free-space speaker has different resonances than vented cabinet speaker. As a further example, if typing speakers by audio performance, a tweeter responds better to a high frequency signal than a midrange speaker does.

Electronic devices, such as mobile radios, often use external speakers. These speakers generally do not have the same physical, electrical, or acoustical properties as the speaker included with the radio. Unfortunately, the audio processing system of prior art mobile radios is optimized for use with the radio's built-in loudspeaker. In other words, the audio processor outputs a signal that is optimized in volume and frequency for the speaker that comes with the mobile radio. Thus other speakers connected to the audio processor will perform poorly because the audio signal sent to them is optimized for a different type of speaker.

Summary of the Invention

In order to overcome the foregoing and other problems, an electronic device is disclosed with a signal processing system that modifies the device's audio output signal parameters depending upon the type of speaker connected to the device. The signal processing system can shift or stretch

the frequency spectrum of the audio signal to account for the various preferred operating frequency ranges of different speaker types. The signal processing system may add audio effects such as stereo and surround sound. The signal processing system can also attenuate the volume of the audio signal by modifying the device's output signal in response to the type of speaker being used.

Some mobile phones have headset mode or car kit modes that allow the user to manually adjust the volume to the headset. The user adjusts the volume by pressing keys on the mobile phone's keypad. These phones are not able to detect what type of speaker or configuration is attached to the headset connector nor are they able to modify the frequency of the audio signal. They cannot stretch or compress audio signals. They cannot take advantage of the configuration of attached speakers to add audio effects such as stereo or surround sound. Adjusting the volume of these phones requires that the user look at the phone to locate the volume attenuation key, a disadvantage while driving. Additionally, these phones are not able to store user audio preferences for different types and configurations of external speakers.

For example, when a mobile phone user switches from an internal speaker to an earpiece speaker (the earpiece speaker and a microphone may be attached to a headset), the audio signal volume may be too high because it is preset for the internal speaker. In this case, the disclosed audio processing system would detect the presence of an earpiece speaker and

automatically adjust the frequency and/or volume of the audio signal so that an improved acoustic experience is provided to the listener.

As another example, when a mobile phone is used with a typical car kit, the speakers provided with a car kit are usually capable of acoustic performance that is superior to the phone's internal speaker. The car kit speakers generally can perform over a greater acoustic bandwidth than the internal speakers can. By shifting or stretching the frequency of the audio signal, the extra performance bandwidth provided by the external car kit speakers can be utilized by the disclosed innovations to create a more pleasant listening experience.

In the presently preferred embodiment, a mobile radio has an audio processing system that receives an audio signal (such as a voice signal or ring tune) from a receiver (or any suitable circuitry in the mobile radio) and modifies the audio signal for improved performance with the speakers connected to the radio. The audio processor may detect and determine the type of speaker by, for example, signature resistors, sensing speaker impedance, feedback analysis, or any suitable method.

As an additional advantage, the user of the mobile radio could store preferred settings for each type of speaker in memory within the mobile radio. When the audio processing system detects an external speaker connected to the mobile radio, the appropriate settings are selected from memory and used to automatically modify the audio signal to the speaker.

Brief Description of the Drawings

The disclosed inventions will be described with reference to the accompanying drawings, which show important sample embodiments of the invention and which are incorporated in the specification hereof by reference, wherein:

Figure 1 depicts a block diagram of a mobile station having speaker dependent audio adjustment capability.

Figure 2 depicts a block diagram of a method of adjusting audio output of a mobile phone.

Figure 3 depicts an audio processing system having speaker dependent audio signal adjustment capability.

Figure 4 shows an audio system composed of a mobile radio with a car kit composed of a hands-free holder and an external audio amplifier that drives external speakers.

Detailed Description of the Preferred Embodiments

The numerous innovative teachings of the present application will be described with particular reference to the presently preferred embodiment. However, it should be understood that this class of embodiments provides only a few examples of the many advantageous uses of the innovative teachings herein. In general, statements made in the specification of the present application do not necessarily delimit any of the various claimed inventions. Moreover, some statements may apply to some inventive features but not to others.

Figure 1 depicts a block diagram of a mobile station **100** that can make use of the disclosed innovations. The mobile station 100 disclosed in this embodiment is a mobile cellular telephone but other types of mobile stations, such as analog cellular telephones and other mobile radios, are within the scope of the disclosed innovations. The mobile station 100 can store a user's audio preferences for particular types of speakers. The mobile station 100 may be able to automatically detect a speaker and determine which type and configuration of speakers are attached to it. This detection may be accomplished by various means such as, for example, by measuring speaker impedance, by inserting a signature resistor, or by designating a particular connector for use with a particular type of speaker. After determining the type and/or configuration of speaker attached to the mobile station 100, logic assembly **118** modifies the audio output signal parameters for improved acoustic performance with the detected speakers. This modification could be, for example, a shift of frequency to accommodate the

bandwidth of the detected speakers. Other possible modifications are adjusting the volume depending upon the type of speaker and the configuration of the speaker, stretching the audio output signal, compressing the audio output signal, adding stereo components to the signal, or adding surround sound components to the signal. As examples of stretching and compressing, the audio output signal could be frequency compressed for speakers with bandwidths narrower than the audio signal bandwidth or frequency stretched for speakers with bandwidths greater than the audio signal bandwidth. Volume adjustment could be accomplished by increasing or decreasing electric current to the speaker. The mobile station 100 includes, in this example:

A control head **102** containing an audio interface, i.e. an internal speaker **104** and microphone **106**. The control head 102 generally includes a display assembly **108** allowing a user to see dialed digits, stored information, messages, calling status information, including signal strength, etc. The control head generally includes a keypad **110**, or other user control device, allowing a user to dial numbers, answer incoming calls, enter stored information, and perform other mobile station functions. In the context of the present invention, the keypad allows the user to enter preferences for types and configurations (such as surround sound configurations) of speakers that may be attached to the mobile station. The control head also has a controller unit **134** that interfaces with a logic control assembly 118 responsible, from the control unit perspective, for receiving commands from

the keypad 110 or other control devices, and providing status information, alerts, and other information to the display assembly 108;

A transceiver unit **112** includes a transmitter unit **114**, receiver unit **116**, and the logic control assembly 118. The transmitter unit 114 converts low-level audio signals from the microphone 106 to digital coding using a codec (a data coder/decoder) **120**. The digitally encoded audio is represented by modulated shifts, for example, in the frequency domain, using a shift key modulator/demodulator **122**. Other data received from the logic control assembly 118, such as station parameters and control information, may also be encoded for transmission. The modulated signal is then amplified by receiver/amplifier **124** and transmitted via an antenna assembly **126**;

The antenna assembly 126 contains a TR (transmitter/receiver) switch **136** to prevent simultaneous reception and transmission of a signal by the mobile station 100. The transceiver unit 112 is connected to the antenna assembly 126 through the TR switch 136. The antenna assembly contains at least one antenna **138** coupled to TR switch 136 by coupler 140;

A receiver unit 116 receives, via the antenna assembly 126, signals transmitted to the mobile station 100. The signal is then amplified by receiver/amplifier 124 and demodulated by demodulator 122. If the signal is an audio signal, it is decoded using the codec 120. The audio signal may then be reproduced by the internal speaker 104. If external speakers are in use, the audio signal may instead be routed to, for example, external earpiece speaker 152 via earpiece connector 150 or to large external

speakers 163 via car kit connector 160. After detecting the presence of an external speaker, logic assembly 118 will modify the audio signal for improved sound reproduction according to the type and/or configuration of speakers detected. For example, if multiple speakers 163 are detected, logic assembly 118 may add stereo components to the audio signal in order to exploit the ability of multiple speakers to produce stereo sound. Logic assembly 118 may detect when external speakers are attached to car kit connector 160 or earpiece connector 150 (and determine the type of external speaker) by, for example, measuring the impedance across the respective connector, checking signature resistors, checking the status of any switches coupled to the connector, checking the standing wave on the transmission line to the speaker, or any other suitable means. Logic assembly 118 may be, or merely a component of, an audio processor. Other signals are handled by the logic control assembly 118 after demodulation 122; and

A logic control assembly 118 usually containing an application specific integrated circuit (or ASIC) combining many functions, such as a general-purpose microprocessor, digital signal processor, and other functions, into one integrated circuit. The logic control assembly 118 coordinates the overall operation of the transmitter and receiver using control messages. The various disclosed embodiments make use of the logic control assembly to modify the audio output signal based upon the type of external speaker in use by the mobile station 100. Generally, the logic control assembly operates from a program that is stored in flash memory **128** of the mobile station. Flash memory 128 allows upgrading of

operating software, software correction or addition of new features. Flash memory 128 is also used to hold user information such as speed dialing names and stored numbers. In the context of the disclosed invention, flash memory 128 can be used to store a user's audio preferences for various speaker types and configurations. For example, when multiple external speakers are detected and logic assembly 118 adds stereo components to the audio signal, stored user preferences could be accessed to control equalization of the right and left channels. As another example, stored user preferences could be used to shift the frequency of the audio signal a set amount depending upon the listening preference of the user for the detected type of speaker. The various disclosed embodiments typically function from this or another section of the mobile station's memory.

In addition to flash memory 128, the mobile station will typically contain read only memory (ROM) **130** for storing information that should not change, such as startup procedures, and random access memory (RAM) **132** to hold temporary information such as channel number and system identifier. In the context of the disclosed inventions, ROM memory 130 may be used to store factory preset (default) values for modifying the audio output signal. These factory-preset values would be used in the absence of user preferences in flash memory 128. RAM memory 132 is used to store information about what type and configuration of external speakers are currently attached to mobile station 100 after logic assembly 118 detects the external speakers.

Figure 2 shows a method of modifying an audio signal depending upon which type of speaker is attached to an audio system. In step **210**, an electronic device, such as a mobile phone, detects which type(s) of external speakers are connected to the electronic device. The electronic device may detect the type of speaker by, for example, signature resistor, sensing speaker impedance, feedback analysis, or any suitable method.

In optional step **220**, the electronic device determines whether there is a user preference stored (for example volume or frequency preferences, such as equalization), in memory for the type of speaker detected. As an example, during this step, in the embodiment discussed in Figure 1, the logic assembly 118 would search flash memory 128 for stored user preferences. If there are user preferences for the type of speaker detected, the preferences are retrieved in step **230** and used to adjust the audio output signal in step **250**. If there are no stored user preferences, default settings for the type of speaker detected will be retrieved in step **240** and used to adjust the audio output signal in step 250. As an alternative, the electronic device may not offer the capability to store user preferred settings, in which case the default settings for the detected speakers will always be used to adjust the audio output signal.

Figure 3 shows a block diagram of an audio processing system **300** having speaker-dependent audio signal adjustment capability. Audio processor **310** accepts an audio signal and detects what type of speaker **330** is attached to the system. Audio processor 310 modifies the audio signal based upon the type of speaker 330 is detected. An optional audio amplifier

320 may be used to drive speaker 330 if there is sufficient signal loss in the transmission line or if speaker 330 has a large acoustic impedance.

Figure 4 shows a diagram of an audio system **400** having a mobile radio **410** with an external audio amplifier **430** that drives external speakers **440**. Amplifier 430 is powered by an external power supply, car battery **450**. Mobile radio 410 is placed in a hands-free holder **420** that has a hard-wired connection to amplifier 430. A connector on the mobile radio 410 mates with a connector on the hands-free holder 430. The audio signal from mobile radio 410 passes over the hard-wire connection from hands-free holder 420 to amplifier 430. At amplifier 430, the audio signal is amplified so that it can drive the external speakers 440. Typically, external speakers 440 have at least twice the acoustic impedance of, and a much greater performance bandwidth than, the speaker built-in to mobile radio 410. Mobile radio 410 detects that it is attached to hands-free holder 420 and modifies its audio output signal to account for the increased audio reproduction capability of external speakers 440. This modification can consist of shifting or stretching the frequency of the output signal. As an example of frequency shifting, an audio processor in mobile radio 410 may shift the entire audio output signal down by, for example, 200 Hz to take advantage of the ability of speaker 440 to generate lower-frequency sound than the speaker built-in to mobile radio 410. As an example of frequency stretching, an audio processor in mobile radio 410 may add high and low frequency components to the original audio output signal so that speakers 440 reproduce more life-like sound. Similarly, if speakers 440 had a

smaller performance bandwidth than the built-in speaker, the audio processor in mobile radio 410 would compress the audio output signal into the reduced bandwidth available so that none of the information needed for speech intelligibility is lost.

As will be recognized by those skilled in the art, the innovative concepts described in the present application can be modified and varied over a tremendous range of applications, and accordingly the scope of patented subject matter is not limited by any of the specific exemplary teachings given.

For example, although the examples discussed above have taught modification of the audio signal in the audio processing system, modification of the signal could occur at any appropriate point in the path from transceiver to speaker. Resistors could be switched in series with the speaker to lower the volume when using earpiece speakers. Alternatively, a feedback loop between the audio processing system and the transceiver could modify the audio signal in the transceiver, before it gets to the audio processor.

For example, although the embodiment depicted in Figure 1 shows the inputs to connector 150 and connector 160 as connected to the digital speech coder 120 in the receiver 116, the audio signal input to connector 150 and connector 160 could be from a ring tone generator or any other appropriate audio signal source in the phone.

For example, although only an earpiece speaker 152 and car kit speakers 163 are shown in Figure 1, numerous other configurations of external speakers, amplifiers, and connectors are possible.

For example, although Figure 1 shows hard-wired connections to external speakers 152 and 164, wireless connections such as infrared, RF, or any other suitable connection are within the scope of the invention disclosed herein.

For example, although Figure 1 discloses a digital mobile station, the invention could also be used with an analog mobile phone.

For example, although signal stretching and compressing have been discussed in the context of frequency stretching and compressing, there are many stretching and compressing techniques known to those skilled in the art that are suitable for use with the disclosed inventions. Several techniques are known which compress or stretch speech signals based upon the relationship of the phonemes in the speech, rather than strictly based upon the frequency of the signal.

For example, although a hard-wired connection between hands-free holder 420 and amplifier 430 is shown in the embodiment of Figure 4, a wireless connection such as RF or optical could be used.

Claims

What is claimed is:

1. A method of adjusting audio output, comprising the steps of:

determining a type of speaker attached to a portable electronic device; and

adjusting, in response to determining said type of speaker, at least one parameter of an audio output signal of said portable electronic device for said type of speaker.

2. The method of Claim 1, wherein said step of adjusting further comprises the step of retrieving, from a memory of said portable electronic device, a user preferred setting for said type of speaker, and wherein said adjusting of said at least one parameter is performed in response to said user preferred setting.

3. The method of Claim 1, wherein said step of adjusting further comprises the step of retrieving, from a memory of said portable electronic device, a default setting for said type of speaker, and wherein said adjusting of said at least one parameter is performed according to said default setting.

4. The method of Claim 1, wherein said adjusting step comprises the step of adjusting the amplitude of said audio output signal.

5. The method of Claim 1, wherein said adjusting step comprises the step of shifting the frequency of said audio signal.

6. The method of Claim 1, wherein said portable electronic device is a mobile radio.

7. The method of Claim 1, wherein said portable electronic device is a mobile cellular telephone.

8. The method of Claim 1, wherein said determining step comprises the step of measuring an impedance of said speaker.

9. An audio system, comprising:

an audio processor having an input for accepting a first audio signal and an output for outputting a second audio signal, said second audio signal comprising a modification of said first audio signal;

an internal speaker coupled to said output of said audio processor; and

at least one external speaker coupled to said output of said audio processor, said external speaker being one of a plurality of types of speaker;

wherein said audio processor is configured to determine which of said plurality of types of speaker said external speaker is, to modify said first audio signal, and to output a second audio signal based on the type of said external speaker.

10. The audio system of Claim 9, wherein said audio processor decreases volume for earpiece type speakers.

11. The audio system of Claim 9, wherein said audio processor modifies the frequency of said first audio signal to better match the signal reproduction capabilities of the type of said external speaker.

12. The audio system of Claim 11, wherein the type of said external speaker is an earpiece type speaker.

13. The audio system of Claim 11, wherein the type of said external speaker is a midrange speaker.

14. The audio system of Claim 9, wherein the type of said external speaker is a piezo-electric.

15. The audio system of Claim 9, wherein said external speaker has an acoustic impedance of at least twice the acoustic impedance of said internal speaker.

16. The audio system of Claim 9, wherein the type of said external speaker is a coil-and-magnet.

17. The audio system of Claim 9, wherein the type of said external speaker is a speaker that has a dynamic range greater than the dynamic range of said internal speaker.

18. A mobile radio for use with an external speaker of a selected type of a plurality of speaker types, said mobile radio comprising:

an antenna;

a receiver having an input and an output, said input coupled to said antenna and said output for outputting a first audio signal;

an audio processor having an input for accepting said first audio signal from said output of said receiver, and an output for outputting a second audio signal; and

at least one connector for connecting the external speaker to said output of said audio processor;

wherein said audio processor is configured to determine that said external speaker is of said selected type and to modify said audio signal from said receiver to provide said second audio signal based on said determination that the external speaker detected is of said selected type.

19. The mobile radio of Claim 18, further comprising an amplifier coupled between said output of said audio processor and said external speaker.

20. The mobile radio of Claim 18, wherein said audio processor modifies said first audio signal by shifting the frequency of said first audio signal when the external speaker is connected to said audio processor.

21. The mobile radio of Claim 18, wherein said audio processor modifies said first audio signal by adjusting the volume of said first audio signal when said external speaker is connected to said audio processor.

22. The mobile radio of Claim 18, wherein said first audio signal is a ring tune.

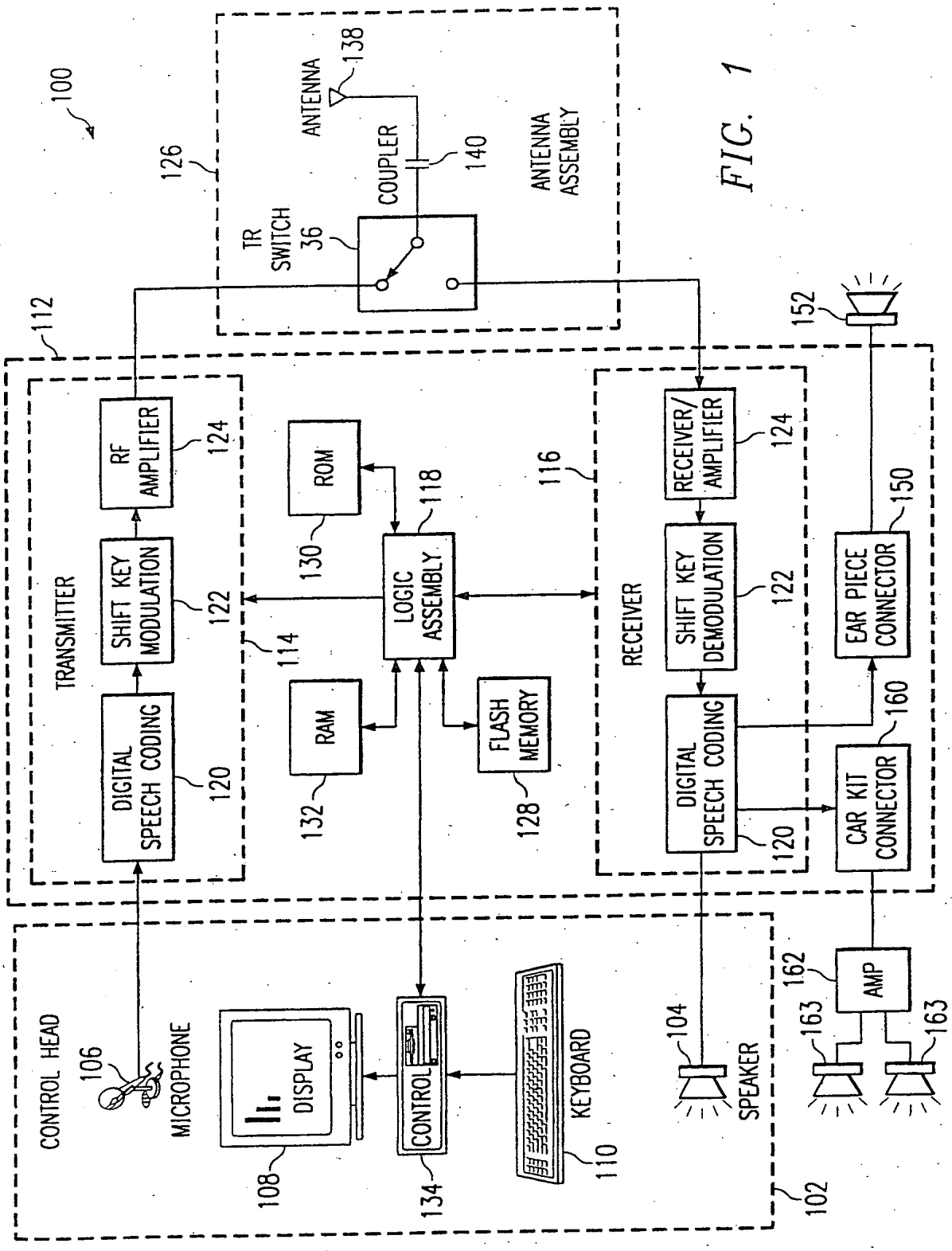
23. The mobile radio of Claim 18, wherein said first audio signal is a voice signal.

24. The mobile radio of Claim 18, wherein said audio processor comprises a digital signal processor.

25. The mobile radio of Claim 18, wherein said audio processor modifies said first audio signal by adding stereo components to said first audio signal.

26. The mobile radio of Claim 18, further comprising a memory, wherein said audio processor is further configured to retrieve stored settings from said memory based on said determination that the external speaker is of said selected type and to use said stored settings to modify said firs audio signal.

27. The mobile radio of Claim 18, wherein said audio processor modifies said first audio signal by compressing said first audio signal


100
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CONTROL
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KEYBOARD
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SPEAKER
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FIG. 1

FIG. 2

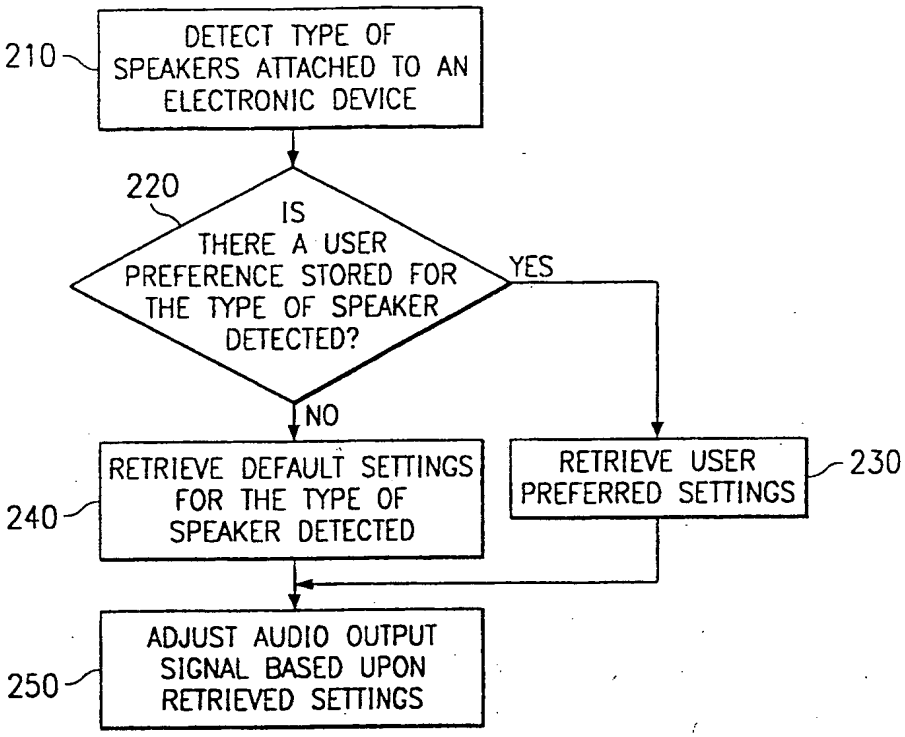


FIG. 3

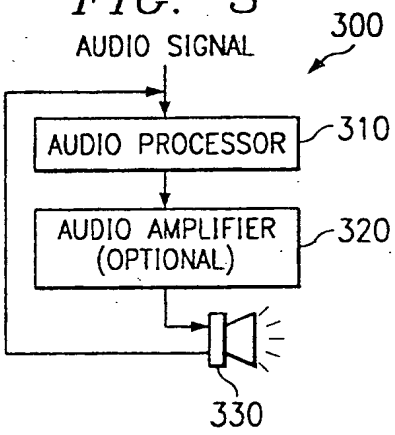
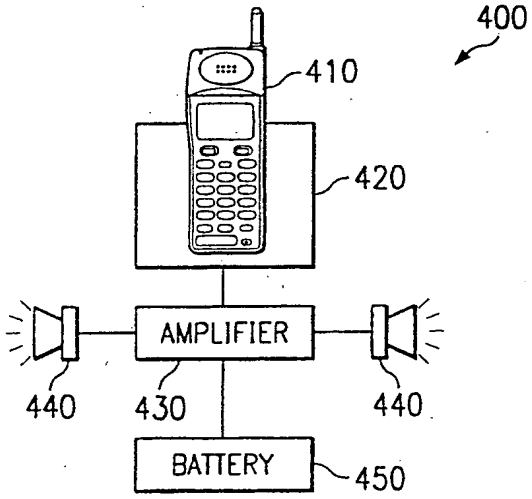


FIG. 4



INTERNATIONAL SEARCH REPORT

In ational Application No
PCT/US 00/24203

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04M1/60

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04M H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 797 102 A (HALLIKAINEN ET AL) 18 August 1998 (1998-08-18) abstract	1-4,7-9, 18,19, 21-24,26
A	column 1, line 4 - line 37 column 1, line 61 -column 3, line 59 figures 1-3	2,10, 14-17

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
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INTERNATIONAL SEARCH REPORT

International Application No
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	FR 2 701 343 A (MURATA MACHINERY LTD) 12 August 1994 (1994-08-12) abstract page 2, line 3 - line 32 page 3, line 22 -page 4, line 11 page 4, line 26 -page 6, line 11 page 6, line 33 -page 7, line 8 figures 1-6	1,3,4,7, 9,10,12, 13,18, 21-23
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A	US 5 257 413 A (WARNER ET AL) 26 October 1993 (1993-10-26) abstract column 1, line 6 - line 9 column 1, line 25 - line 29 column 1, line 41 -column 2, line 59 figures 1,2	1,4,6,9, 10,12, 13,18, 19,21
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INTERNATIONAL SEARCH REPORT

Information on patent family members

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